Continental J. Applied Sciences 9 (2): 31 - 36, 2014
© Wilolud Journals, 2014
Printed in Nigeria
ISSN: 1597 – 9928
http://www.wiloludjournal.com
doi:10.5707/cjapplsci.2014.9.2.31.36

THE BENEFICIATION OF GRAPHITE BY FLOTATION USING A LOCALLY SOURCED COLLECTOR - SOYBEANS OIL

NUHU, STEVEN KUBA
Department of Mineral and Petroleum Resources Engineering, School of Engineering
Plateau State Polytechnic, B/Ladi, P. M. B. 02023, Bukuru, Plateau State, Nigeria

ABSTRACT

Soya beans oil was used as possible substitute for oleic acid a collector and kerosene as frother for recovering graphite from its impurity. The highest recoveries from 300g graphite using oleic acid and soya beans were 131.4g and 129.0g respectively. The chemical analysis to determine the silica content in each was conducted and contained 79.30% and 790.10% in that order with corresponding values of carbon content weight percentage of 68.40% and 64.39% in that order. The result shows that soya beans oil is a potential substitute for oleic acid - a collector with kerosene as frother for the beneficiation of graphite ore.

KEYWORDS: Soya beans oil, Oleic acid, Collector, Frother, Modifier, Beneficiation

Received for Publication: 25/08/14 Accepted for Publication: 11/12/14

Corresponding Author: kubasteven@yahoo.com

INTRODUCTION

Graphite was used in the 4th millennium B. C Marica culture to create a ceramic paint to decorate pottery during the Neolithic Age in Southern Europe in some years before; there was a discovery of enormous graphite on the approach to grey knot which was found very useful in making sheep (Hart *et al*., 2005).

The ancient Rome scribe wrote on papyrus (an early form of paper) with a thin metal rod called stylus which left but readable marks. Other early styluses were made of lead. Today we still call the core of a pencil the ‘lead’ even though it is made from non-toxic graphite (Klima *et al*., 2010).

Natural graphite occurs in many parts of the world in fair abundance and it has been used for ages in various applications. Quite a number of countries hold the key position in graphite production in tonnage; South Korea is the largest producer in the world followed by Austria. (Goh *et al*., 2005).

Depending upon the mode of occurrence and origin, graphite is graded into three forms:
(1) Flake - found in metamorphosed rocks as vein deposit (2) Crystalline (lumpy) – found as fissure filled veins (3) Crypto crystalline (amorphous) – form in metamorphosed coal beds (Klima *et al*., 2010).

Flake graphite is a form of elemental carbon; it is one of the three allotropes forms which the element carbon exists in nature (Fuerstenau and Somasundaran, 2003). The other two being coal and diamond. It crystallizes in hexagonal system in platy form but it is rare the perfect crystal of graphite have been found. Graphite is of metamorphic origin, usually found as veins, lenses, and pockets, and as thin lamina disseminated in the gneisses, schist and phyllites. It has black to steel grey color and usually leaves a black streak on the hand when touched because of its extreme softness and greasiness. It is opaque even in the finest particles. Graphite is a good conductor of heat and electricity (Klima *et al*., 2010). It has high refractoriness. It can stand a temperature up to 3000˚C in an inert atmosphere though in the presence of oxygen it burns between 600°C and 720°C. It is unaffected by most of the acids and reagents but yields graphic acids on treatment with a mixture of potassium nitrate and nitric acid (Crozier, 2000).

In nature, graphite is found usually in mechanical association with feldspar, mica, quartz, pyroxene, rutile, pyrites and apatite. These impurities associated with amorphous graphite are shale, slate, sandstone, quartz and limestone (Berbian *et al*., 2005).

Graphite is valued for its good conductivity of heat and electricity and high refractoriness. The utility of graphite is dependent largely upon its types. The flake type is found to possess extremely low resistivity decreasing with increase in flaky particles. In addition, the bulk density decreases progressively as the particles become more and more flaky, because of this property in flake graphite; it finds a large use in the manufacture of carbon electrodes, plates and brushes required in the electrical industry and dry cell batteries. In the manufacture of plates and brushes, however, flake graphite has been substituted to some extent by synthetic amorphous, crystalline graphite and acetylene black. Graphite electrodes serve to give conductivity to the mass of manganese dioxide used in dry batteries. The manufacture of crucibles is served best by flake graphite, although crystalline graphite is also used. (Andrews, 2000). Graphite crucibles are manufactured by pressing a mixture of graphite, clay and sand and fixing the pressed articles at a high temperature. They are used for melting non-ferrous metals, especially brass and aluminum. Coarse-grained flake graphite from Malagasy is regarded as standard for crucible manufacture (Broekaert, 2004).

Flake graphite contains 80 to 85% carbon used for crucible manufacture. Graphite with 93% carbon and above is preferred for the manufacture of lubricants and graphite with 40% and 70% carbon is utilized for foundry facings (Gaudin, 2007). Natural graphite refined or otherwise pure has carbon content not less than 95% is used in the manufacture of carbon rods for dry battery cells, this grade of graphite is imported from Ceylon and England (Agar, 2005). After the Second World War, clay-graphite crucibles were replaced by silicon carbide crucibles bonded by graphite. Such crucibles are now manufactured in USA and other advanced countries (Agar, 2000). All grades of graphite especially high-grade amorphous and crystalline graphite having colloidal properties, which is, remaining in suspension in oil, are used as lubricants.

Graphite has an extraordinary low-coefficient of friction under practically all working conditions; this property is invaluable in lubricants. It diminishes friction and tends to keep the moving surface cool. Dry graphite as well as graphite mixed grease is utilized as a lubricant for heavy and light bearings. Graphite greases is used as a heavy-duty lubricant where high temperature may tend to remove the grease (Ahmed and Jameson 2009).

Graphite bricks of high purity are used as moderators in an atomic reactor. In the nuclear field, graphite is a good and convenient material as a moderator but this is only true if the graphite is low in certain neutron elements notably boron and the rare earths and is of consistent quality particularly with regard to density and orientation. The latest invention in the use of graphite is in the blast furnace operation, view of lack of coking coal in Austria; it is likely that use of graphite in blast furnace will be developed on a commercial scale (Alexander *et al*., 2000)

Graphite can only be confused with the mineral molybdenite which is metallic bluish silver in color. However, molybdenite is much denser and has a silver blue streak. Most graphite is produced through the metamorphism of organic material in rocks. Even coal is occasionally metamorphosed into graphite. Some graphite is found in igneous rocks and also as nodules inside of iron meteorites (Araujo *et al*., 2005).

Table 1: The World Top Producers and Exporters of Graphite

S/N	Country	Year	
		2005	**2006**
1	Canada	280,000 t	280,000 t
2	Brazil	75,515 t	75,600 t
3	China	720,000 t	720,000 t

Source: (Klima *et al*., 2010)

In Nigeria, graphite occurs in states like;
(1) Taraba -Gayama, Hossere, Nuwa, Jauro (2) Adamawa-Mayo belwa (3) Bauchi-Ningi
(4) Kaduna-Birnin Gwari

Graphite is mined around the world by both open pit and underground methods. Flake graphite and amorphous graphite are both mined by open pit and underground in Sri Lanka. In Ceylon, U.S.A. and Mexico, graphite is extracted by underground mining. In Ceylon, the deepest working level has gone to a depth of 480m. In Malagasy Republic, it is obtained by hydraulic method (Das *et al*., 2005). The open pit mines usually employ equipment to scoop up the ore which is usually put in trucks and moved to plants. Since the original rock is usually weathered, this amounts to moving dirt or impurity with flecks or pieces of graphite in the pit. The underground graphite mines employ drilling and blasting to break up the hard rock which is then moved by mine cars pulled by a locomotive vehicles to the surface and then to the plant.

Graphite is a natural floater. Flotation has become the accepted method of beneficiation of graphite (Crawford and Ralston, 2008). Flake graphite from disseminated deposits is difficult to concentrate, therefore, a number of processes have been evolved by different countries. It has been found difficult to recover refined graphite from rough concentrate. This difficulty is due to the fact that fine grinding is not allowed in case of flake graphite because by resorting to this process of grinding there are chances of flakes being cut by quartz and other gangue materials which reduces the size and also lowers the price and value of the graphite. Graphite required for crucible manufacture must be 8 to 60 mesh (Jowett, 2006).

In view of this, the graphite in Ningi area of Bauchi State, Nigeria, was collected and floated using soya beans oil (locally sourced reagent) as collector in an attempt to substitute the conventional (oleic) ones with the view of reducing the cost of importing reagents which are conspicuously expensive. Kerosene, one of the conventional frothers was used and sodium hydroxide as a modifier to experiment their extent of recovery compared to that of the conventional reagents – oleic acid, a collector which is normally used in concentrating the graphite ore and other materials.

Aim/Objectives

The aim of this work is to investigate for the extent of recovery made by the locally sourced reagent. If the recovery is high, the reagent will be used as an alternative to replace or substitute the conventional ones that are very expensive and reduce cost of importation.

Apparatus and Chemicals Used

The following apparatus played a good role in the conduct of this research. They include; Denver flotation cell, rod mill, pestle and mortar, triple beam balance and ceramic bowl. Others are x-ray fluorescent spectrometer, trays, pH meter, spoon, beaker and syringe.

The chemical used were distilled water, sodium hydroxide and oleic acid. While other materials include soya beans oil, kerosene and graphite ore.

METHOD

A sample of ground graphite was weighed up to 300g using the triple beam balance. Distilled water of up to 1000cm^3 was measured and mixed with the graphite ore, poured into the flotation cell and agitated for 2 minutes at the speed of 1500rpm. During the agitation process, three drops of regulator (sodium hydroxide) was added to it as a pH adjuster and conditioned for three minutes. Thereafter, three drops of oleic acid (conventional collector) was added and conditioned for two minutes. After this, three drops of kerosene (conventional frother) was added and conditioned for two minutes. Immediately after the conditioning/agitation, air was allowed in and froth was emerged and collected in a clean tray by scooping using a clean spoon. After removing the froth, the pulp was agitated for one minute and air allowed into it again, more froth was formed and scooped. This continued until froth was no more observed or formed again. The froth collected was dried and weighed after twenty-four hours. The water containing the gangue was allowed to settle for twenty-four hours too after which it was decanted and the tailing dried, weighed and recorded.

This process was repeated four times using soya beans oil (locally sourced collector) in the place of oleic acid maintaining kerosene as conventional frother and the same weight of the graphite ore.

Chemical Analysis of Graphite

The chemical composition and the respective percentage composition of both the unbeneficiated and beneficiated graphite were determined by the use of x-ray fluorescent spectrometer (Avotins *et al*., 2004).

Ash Analysis of Graphite

The beneficiated sample of the graphite up to 30g was weighed, poured in a crucible, placed in a muffle furnace, and left for thirty minutes at a temperature of 110˚C in order to drive off moisture. After the thirty minutes of firing, it was removed and placed in a desiccator to cool. After being cooled, it was then weighed the second time. In this analysis, two parameters were calculated; percentage purity and percentage ash content (Bradshaw and O’Connor, 2006).

$$\text{Percentage Purity (\% P)} = \frac{W_1 - W_2}{W_1} \times 100\% \quad \text{(Bradshaw, 2005)}$$

$$\text{Percentage Ash Content (\% AC)} = \frac{W_2}{W_2} \times 100\% \quad \text{(Crozier, 2004)}$$

Where: W_1= initial weight and W_2 = final weight

RESULTS AND DISCUSSION

Table 2: Beneficiation of Graphite Using Oleic Acid and Soybeans Oil as Collectors

Sample (g)	Collector	Weight of Concentrate (g)	Weight of Tailings (g)
300	Oleic acid	131.4	168.4
300	Soya beans oil	129.0	170.8

Source: Nuhu, S. K. (2014) Experiment conducted at NMDC Jos.

Table 3: Chemical Analysis of Tailings from Graphite Ore Floated with Oleic Acid and Soybeans by X-Ray Fluorescent Spectrometer (XRF)

Compound	Collector	
	Oleic Acid (%)	Soybeans Oil (%)
SiO_2	79.30	79.10
SO_2	2.70	2.60
K_2O	1.71	1.67
Ca_2O	0.90	1.20
TiO_2	3.04	3.09
V_2O_5	0.57	0.55
Cr_2O_5	0.037	0.041
MnO	2.10	2.10
Fe_2O_3	6.70	7.01
NiO	0.03	0.04
CuO	0.41	0.16
ZnO	0.20	0.23
As_2O_4	0.059	0.06
B_2O	0.86	0.88
Yb_2O_3	0.032	0.020
Re_2O_3	0.051	0.04
PbO	0.17	0.31
SiO	0.32	0.21

Source: Nuhu, S. K. (2014) Experiment conducted at NMDC Jos.

Table 4: Ash Analysis of Beneficiated Graphite Using Oleic Acid and Soybeans Oil

Collector	Weight W_1 (g)	Weight W_2 (g)	Purity (%)	Ash Weight (%)	Carbon Content (%)
Oleic acid	30.00	9.48	68.40	31.60	68.40
Soya beans oil	30.00	10.68	64.39	35.61	64.39

Source: Nuhu, S. K. (2014) Experiment conducted in NMDC Jos.

DISCUSSION

Table 2 shows the results of weight of graphite concentrate and tailings obtained after flotation process with oleic acid which yielded 131.4 g concentrate and 168.4 g tailing respectively. With soya beans oil it produced 129.0g concentrate and 170.8g tailings in that order. This shows that soya beans oil which is a locally sourced (collector) reagent recovered a close quantity of graphite to oleic acid.

Table 3 gives the results obtained from the chemical analyses of tailings after using oleic acid and soybeans oil on graphite as 79.30% and 79.10% respectively of SiO_2 removed. In the same vein, soybeans oil has favorably removed 1.67%, 3.09%, 2.10% and 7.01% of K_2O, TiO_2, MnO and Fe_2O_3 as against 1.71%, 3.04%, 2.10% and 6.70% by oleic acid into the tailings. This means that soya beans oil is capable of removing substantial amounts of gangue equal to or better than oleic acid. However, soya beans oil does not act well on the removal of CuO like oleic acid did but did better on several others than the oleic acid.

Table 4 indicates that soybeans did not removed ash as much as oleic acid, although the difference is not that wide (35.61 wt% and 31.60 wt % respectively). However, percentage purity obtained by the use of soybeans oil is favorable to that of oleic acid (64.39% and 68.40% in that order).

CONCLUSION

From the results obtained in Tables 2, 3 and 4, it shows that soya beans oil as a locally sourced collector removes high values of gangue and recovers close values of concentrate as the conventional collector (oleic acid). Therefore, soya beans oil can be used to substitute oleic acid where the concentration of graphite is desirous.

RECOMMENDATION

More analysis can be carried our using other locally sourced oils in comparison with oleic acid to obtain the best locally sourced reagent. In addition to this, proximate analysis can be carried out to confirm the purity and carbon content percentage of the graphite.

REFERENCES

Agar, G. E. (2000). Optimizing the Design of Flotation Circuits, CIM Bull., 73, 173.

Agar, G. E. (2005). The Optimization of Flotation Circuit Design from Laboratory Rate Data, in Proc.15th Int. Min. Proc. Cong., Cannes, 100.

Ahmed, N. and Jameson, G. J. (2009). Flotation Kinetics, Mineral Processing and Extractive Metallurgy Review, 5(1-4), 77.

Alexander. D. J., Runge, K. C., Franzidis, J. P. and Manlapig, E. V. (2000). The Application of Multi-component Flotation Models to Full Scale Flotation Circuits, 7th Mill Operators Conference, Aus. IMM Kalscorlie, Australia (Oct.), 167-178.

Andrews, P. R. A. (2000). Review of Developments in Casseterite Flotation in Respect of Physico-chemical Considerations, Minerals, Materials and Industry, IMM London 345.

Araujo, A. C., Vianna, T. P. M. and Peres, A. E. C. (2005). Flotation Machines in Brazil – Coloumns Vs Mechanical Cells, in Proc. Centenary of Flotation Symp., ed. Jameson G., Aus. IMM Brisbane (Jun.), 187-192.

Avontins, P. V., Wang, S. S. and Ngara, D. R. (2004). Recent Advances in Sulphide Collector Development in Reagents for Better Metallurgy, ed. P. S. Malukurla. SME, Inc., Littleton.

Barbian, N., Hadler, K., Ventura-Medina, E. and Cilliers, J. J. (2005). The Froth Stability Column:Linking Froth Stability and Flotation Performance, *Minerals Engineering*, 18(3), Mar. 317-324.

Bradshaw, D. and O'Connor, C. (2006). Measurement of the Sub-process of Bubble Loading in Flotation Minerals Engineering. 9(4), 443-448.

Bradshaw, D. J., Oostendorp, N. and Harris, P. J. (2005). Development of Methodologies to Improve the Assessment of Reagent Behavior in Flotation with Particular Reference to Collectors and Depressant. *Minerals Engineering*, 18(2), 239-246.

Broekaert, E. (2004). New Processes for Casseterite Ore Flotation in Mineral Processing and Extractive Metallurgy, ed. M. J. Jones and P. Gill, IMM, London, 453.

Crawford, R. and Ralston, J. (2008). The Influence of Particle Size in Mineral Flotation, *Int. J. of Min. Proc.*, 23, 1-24.

Crozier, R. D. (2000). Non-metallic Mineral Flotation, Industrial Minerals, (Feb.), 55.

Crozier, R. D. (2004). Plant Reagents: Part 1: Changing Pattern in the Supply of Flotation Reagents, *Mining Mag*. (Sept.), 202.

Das, B., Prakash, S., Biswal, S. K., Reddy, P. S. R. and Misra, V. N. (2005). Studies on the Beneficiation of Iron Ore Slimes Using the Flotation Technique, Proceedings of Centenary of Flotation Symposium, Aus. IMM: Melbourne, Brisbane, Qld, 6-9 Jun. (CD ROM) 737 – 742).

Fuerstenau, M. C. and Somasindaran, S. (2003). Flotation, in Principles of Mineral Processing, ed. M. C. Fuerstenau and K. N. Han, Soc. For Mining, Metallurgy and Exploration Inc., SME, Colorado, USA.

Gaudin, A. M. (2007). Flotation. McGraw-Hill, New York.

Goh, S. W., Buckley, A. N., Lamb, R. N. and Woods, R. (2005). Distinguishing Monolayer and Multilayer Adsorption of Thiol Collectors with ToF-SIMS and XPS, in Proc., Centenary of Flotation Symp., ed. G. Jameson, Aus, IMM Brisbane (Jun.) 439 – 448.

Hart, B., Biesinger, M. and Smart, R. St. C. (2005). Improved Statistical Methods Applied to Surface Chemistry in Minerals Flotation, in Proc., Centenary of Flotation Symp., ed. Jameson G., Aus. IMM Brisbane (Jun.) 457 – 465.

Jowett, A. (2006). Gangue Mineral Contamination of Froth, Brit. Chem. Engineering., 2, 330 – 333.

Klima, M. S., Aplan, F. F. and Luckie, P. T. (2010). Elements of Mineral Processing: Lecture Notes. The Pennsylvania State University. Pro Copy Course Works.

Nuhu, S. K. (2014). Froth Flotation Analysis of Graphite Ore: Carried Out in the Laboratory of National Metallurgical Development Council (NMDC) Jos, (Jun.).